Improved Control Technique for Reduction in EMI Generation in PV Grid Inverter

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Abstract: In grid connected solar PV system the main cause of generation of electromagnetic interference is switching of power semiconductor devices present in the converter or inverter. The amplitude or level of generated EMI depends upon the dv/dt & di/dt rating of the semiconductor devices. Also depends on multiple other factors like PCB layout, parasitic components, and grounding technique etc. Researchers have suggested many techniques to solve the problem of EMI generated in converter or inverter circuits. However, none of the suggested methods eliminates the problem of EMI. In this paper, a new improved control technique is presented for reduction in EMI generated by Inverter in a gird connected Solar PV environment. Implementing the proposed method and its performance is assessed by experiments. When compared with the CISPR standards results show good efficiency.

***Index Terms*– Grid PV system, EMI, dv/dt, di/dt, Inverter topologies, CISPR**

I. INTRODUCTION

The use of grid-connected inverters in non-conventional energy sources are increasing rapidly. Due to the limited accessibility of fossil fuels and the increasing global electricity demands, only promising solutions are the renewable energy resources such as wind, solar, tidal, biomass energy. The energy harnesses from renewable energy resources have substantial limitations, since their produced power is unregulated and discontinuous in nature. The power generation of PV system depends on the solar insolation and neighboring temperature. When the solar insolation is even, the output of a PV system shows a single operating point where the power generated is maximum [1], [2]. The photovoltaic cells convert solar energy into direct current. To feed the electrical power to the grid connected inverters are used, which convert the output DC of PV into AC. The inverter is a vital element in grid connected PV systems.

Several power electronics inverter interface for three-phase grid connected PV system are available, named as self-commutated inverter, line commutated inverter. Self-commutated inverter are also classify as voltage source inverter and current source inverter. Further, voltage source inverter is classifying as voltage control mode and current control mode [3], [4]. Further, arrangement of different inverter topologies are also proposed on the basis of different groups like number of power processing stages, position of power decoupling capacitor, use of line frequency transformer. In addition, different types of inverter or converter topologies are used like Buck converter, Boost converter, Zeta converter, Matrix converter, Multi-level Inverter etc. [5].

Multi-level Inverter used in grid connected inverter system is having greater results as compared to other grid connected inverter configuration. For inverter switching purpose, there are various switching techniques available. In this paper, we only concentrate on hard switching and soft switching techniques [6]. In addition, hard switching technique has limitation like more switching losses. Soft switching techniques are used to minimize the switching losses of power semiconductor devices used in inverters. MLI is the obvious choice of grid connected PV system designer because several benefits like less harmonics generation, minimum stress on switching devices and applicable in high voltage and medium power. Due to reduced level of dv/dt in MLI, the generation of electromagnetic interference is less as compared to other inverter topologies.

The main reason of generation of EMI in inverters is the switching of power semiconductor devices. Switching of is essential part in any converter or inverter to get the desired output. In case of grid connected PV system, generation of EMI is a serious concern due to the interaction of these undesirable interference signals or noise to the locally based controller or communication system creates malfunctions. Hence, it is necessary to reduce the level of EMI to safe limit for safe operation of nearby sensitive devices. To achieve this, different researchers have presented different control strategies. For CM noise an anti-phase winding used in boost converter, EMI filters are used either active or passive for minimization of EMI generation. However, there is still scope for research in EMI mitigation area in grid connected PV system inverters. In this paper, soft switching based EMI reduction technique is proposed for inverters connected in grid PV systems. The proposed control technique is used to subdue the peaky EMI. Section II descries the grid connected PV system. In section III causes of EMI generation in inverters discuss. Section IV various standards related to EMI explains. In Section V, the improved control strategy and section VI results are discussed. Finally, conclusions are lists in section VII.

II. GRID CONNECTED SYSTEM

Grid connected solar Photovoltaic system is shown in fig 1.1. It consists of a PV array, Linear Impedance Stabilization Network & Three Phase Inverter connected to the grid. The output of PV array fed to the three-phase inverter through linear impedance stabilization network. The LISN is used for calculating the electromagnetic interference generated by the inverter circuit. The output of LISN is feed to a control strategy circuit. This control strategy circuit is used to generate required signal for the switching circuit. The switching controller output is feed to power semiconductor devices of three-phase inverter circuit for their switching operation. For complete working of grid connected solar PV system, brief description of each component are given below.

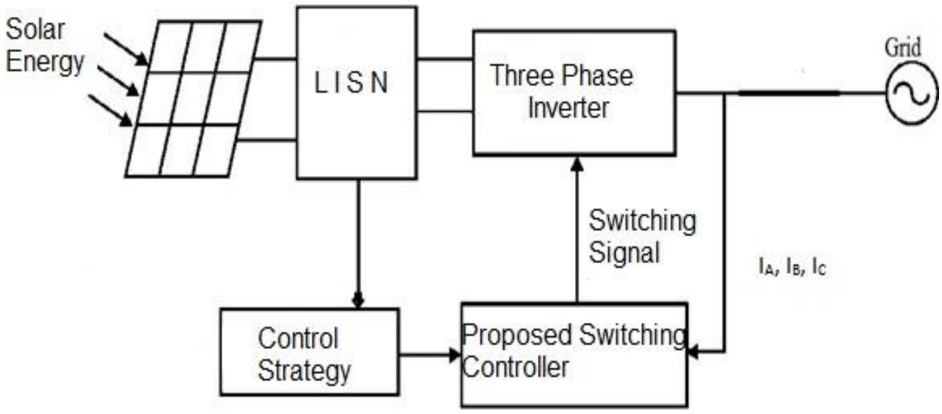


Fig. 1.1 Grid connected solar Photovoltaic system

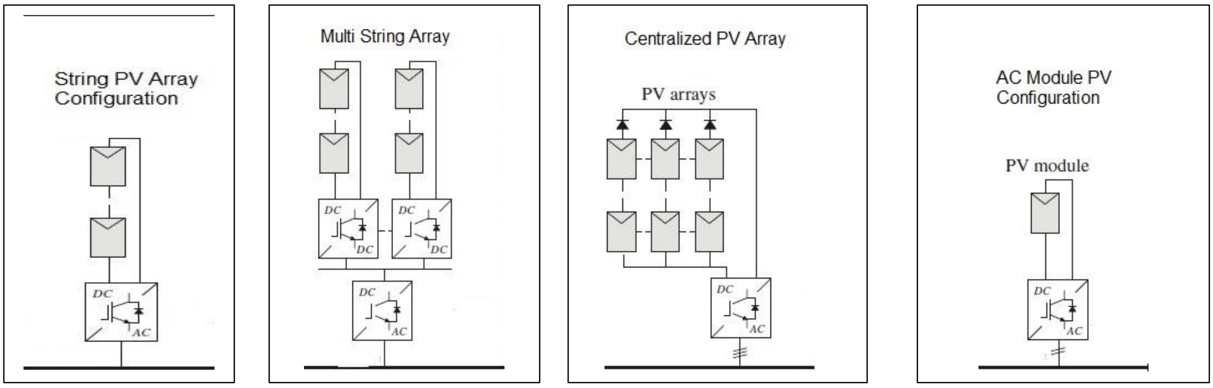
Photovoltaic (PV) Array: The PV array consists of PV cells arranged in parallel and series combination to generate the preferred DC voltage and current. Generally, silicon semiconductor material is used to fabricate PV cell. The popularly available PV module having 36 or 72 cells connected in series to form a PV array. The PV array classified into four categories. They are categorizing into central PV configuration, string PV configuration, multi-string PV configuration, and module PV configuration.

Centralized PV Array Configuration: This type of array configuration was used for large PV systems from 100kW to several megawatts for the grid connected PV system as shown in fig 1.2 (C). In centralized configuration, only one inverter is used to convert DC power into AC power, the input to the inverter feed from a large number of PV array and the output of this inverter is fed to the grid in on grid system. In central configuration, strings of series PV array are to achieve higher voltage level. This type of configuration is simpler and control mechanism is easy. However, it has many limitations, such as only single MPPT can be installed in the type of configuration, which would reduce the power generation due to the module mismatch and partial shading. In addition, inverter used in this configuration injects many harmonics, which reduces the power quality.

String PV Array Configuration: In string PV array configuration, only single PV string is connected to the inverter and inverter is connected to the gird or load as shown in fig 1.2 (A). This improves the total generated power with the help of MPPT technique. To increase the voltage level of the system, additional PV strings can be added into the existing structure with minimum changes. By inserting the additional string, the output of MPPT will be affected and it has to be set as per requirement.

Multi-String PV Array Configuration: As the name suggest, this type of PV array configuration multiple string of PV array is used as shown in fig 1.2 (B). Each PV array string has individual DC-DC converter. The outputs of individual DC-DC converters are fed to a common DC BUS. The inverter is input terminal is connected to the common DC BUS and the output terminals of inerter are connected to the grid or load. Expansion of the system is easier in this configuration. However, for connecting the output of individual DC-DC converter to the common DC BUS long DC cables are required. The use of long DC cables will increase the EMI issues as they acts as an antenna for radiating EMI.

AC Module PV Array Configuration: The AC module topology is intended for smaller systems and domestic use. In this configuration, one Inverter is dedicated for one PV module. The inverter is mounted on the panel itself. However, in this type of configuration DC-DC boost stage or step-up transformer is necessary for increasing the voltage level.



(A) (B) (C) (D)

Fig. 1.2 PV Array Configurations for Grid connected Solar Photovoltaic system

Linear Impedance Stabilization Network (LISN): Line impedance stabilization networks (LISN) are required element for measurement of conducted EMI emission in grid connected PV system. LISN creates known impedance that allows conducted EMI measurements to be conducted and isolated these signals from the power source. The LISN is inserted between the PV array and the inverter circuit for measuring the CM noise. Fig. 1.3 shows the common LISN used in inverter circuit.

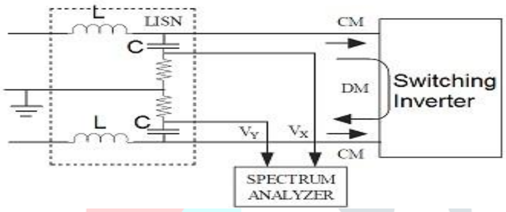


Fig. 1.3 LISN connected to Switching Inverter

Three Phase Inverter: Three-phase inverter is a vital component of the grid connected PV system. It converts DC nature of electrical energy comes from the solar photovoltaic array into AC nature and fed it to the grid system. There are various topologies of power electronics inverters interface for three-phase grid connected PV system. Some of the important inverter topologies are Buck, Boost, Buck-Boost, Zeta converter, DC Link inverter, and Matrix converter topology etc. In this paper, we have used voltage source inverter for converting dc power into ac power. Figure 1.4 shows the system consists voltage source inverter, LCL filter, and the inverter controller. The diode connected to the solar PV array is used to avoid the situation when PV panel work as load. This situation occurs when there will be no solar energy available, at this time, to protect the flow of reverses current from grid to PV panel.

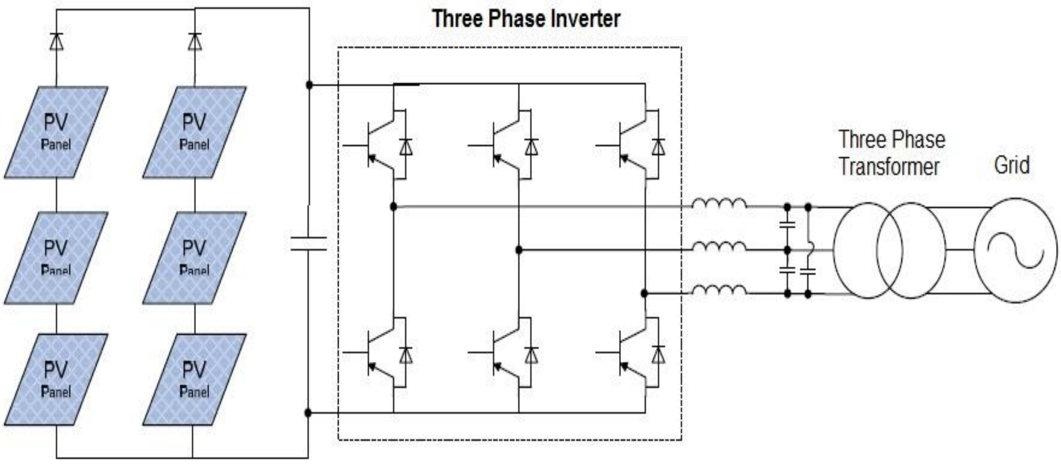


Fig. 1.4 Inverter Configuration

III. ELECTROMAGNETIC INTERFERENCE GENERATION

Electromagnetic interference generates in inverter of grid connected PV system due to frequent turn on and turn off power semiconductors switching devices associated with Inverter. Due to fast switching of switching devices, the rate of change of voltage is high and it will generate the electromagnetic interference in the circuit. Another reason for generation of EMI is the circulating current flowing in the inner loop of the circuit. In addition, in grid connected PV system the leakage current will also play an important role in generation of EMI. DC cable from PV array to inverter circuit will also acts as an antenna for radiated emission.

In the present system we only concentrate on EMI generated due to inverter switching, i.e. the major cause of EMI generation in the circuit. To get the desired output from the inverter circuit, switching of power semiconductor devices are essential. Nowadays, there is huge demand of compact and high efficiency inverters, to achieve that fast switching devices like MOSFET etc. are implemented in converter / inverter circuits. However, this fast switching speed generates EMI that creates problem to the controller circuit itself as well as other nearby controller and sensitive equipment. The source of differential mode (DM) EMI is the high current switched by SCRs or diodes at very fast rate, i.e. di/dt. Parasitic capacitors to the ground are also prominent cause for common mode (CM) EMI. There are various other reasons for generation of EMI like manual, natural, environmental etc. They are not relevant to the topic hence not important to discuss here.

IV. Frequency standards for EN 55022 and CISPR 22

There are many international standards available to control EMI emission due to power electronics converter / inverters. EN55022 and CISPR22 are the EMI standards used for analyzing the performance of the electromagnetic interference generated by the grid connected PV system. In these standards, the EMI is expressed in terms of dBµV. In case of EN55022, the EMI quasi peak value for 0.15 to 5 MHz, 0.5 to 5.0 MHz & 5.0 to 30.0 MHz are 66-56, 56 and 60 dBµV respectively. Same as for average value of EMI for 0.15 to 5 MHz, 0.5 to 5.0 MHz & 5.0 to 30.0 MHz are 56-46, 46 and 50 dBµV respectively. Similarly for CISPR 22, from frequency range 0.15 to 0.5 MHz the quasi peak value is 8912.5 (1995) and average value is 79 (66). Also for frequency range from 0.5 to 30.0 MHz the quasi peak value is 4467 (1000) and average value is 73 (60). It represents that if the level of generated EMI is under these values then it will not create any disturbances or malfunctions to the nearby sensitive electronics devices. It also represent the immunity level of any device or circuit.

V. Control Strategy

For reduction in electromagnetic interference generated in the proposed grid connected solar PV system, soft switching technique will implement.

Inverters having the Zero Voltage Switching or soft switching techniques can attain high power density, high efficiency, and low switching losses in grid connected inverters while operating at a fixed frequency. In addition, this method will also contribute to less conducted EMI emissions. To compute the effect of the soft switching technique on the conducted EMI reduction, a simulation comparison of the EMI profiles of VSI, employing the soft switching technique and the Hard Switching (HS) method [9] respectively, carried out. Fig.1.5 shows the controller schematic diagram.

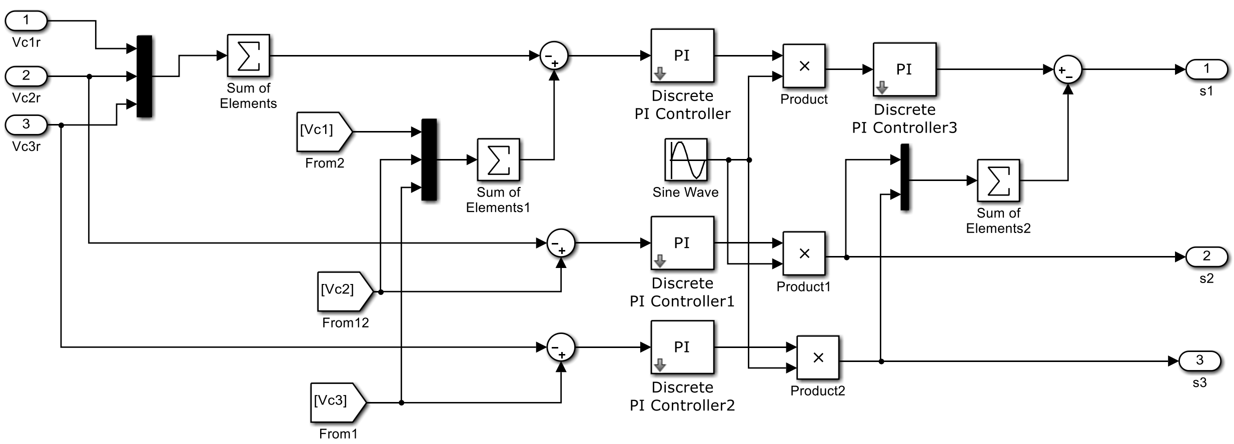
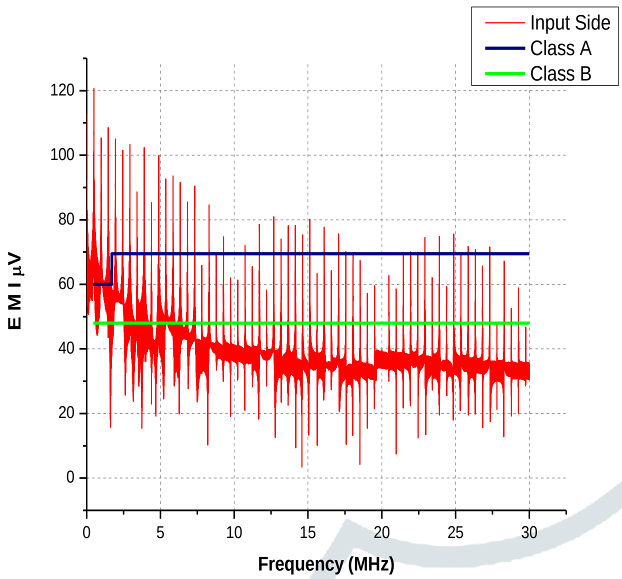


Fig.1.5 Proposed Controller for EMI Reduction

VI. Result and Discussion

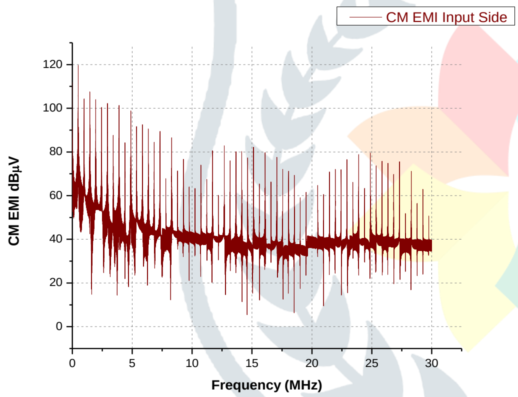
For the determination of EMI generated in Grid Connected Solar PV system, simulation is performed on the Simulink model of the existing system. Firstly, the system is simulated for conventional (hard) switching technique & determines EMI generated in the system. Fig 1.6 (A) shows the total EMI generated, fig (B) shows the CM EMI and fig (C) shows the DM EMI of the present set up respectively. From these figure it clearly indicates that in case of conventional (hard) switching the magnitude of EMI is more at some frequency region than the specified limit given in standard CISPR 22.

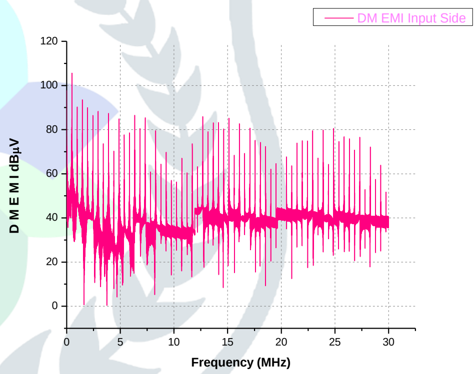
By implementing, the proposed improved switching technique on the existing setup of grid PV system. The magnitude of generated EMI & the simulated result showed in fig. 1.8. Fig 1.8 (A) shows the total EMI generated, fig (B) shows the CM EMI and fig (C) shows the DM EMI of the existing solar PV grid connected system respectively. From the fig. 1.8 it observed that by implementing the improved new switching technique, the magnitude of EMI is reduces. In much of frequency range the magnitude of EMI is well below the standard value of CISPR 22. This indicates that improved control (switching) reduces the generated EMI level satisfactorily.



Sr. No.	Frequency	EMI dBµV	CISPR 22 Average (dBµV)
1	100 kHz	78.44	56-46
2	200 kHz	80.72	56-46
3	500 kHz	87.33	56-46
4	1 MHz	82.54	46
5	3 MHz	80.52	46
6	5 MHz	74.23	46
7	10 MHz	65.84	50

(A)





(B) (C)

Fig. 1.6 Total EMI, CM EMI & DM EMI in Grid Connected PV system

The proposed control strategy has demonstrated the capability of intelligent controller for grid connected solar PV system to minimize the level of generated electromagnetic interference. The result of the proposed control strategy have been observed for grid connected solar PV of different power capacities, i.e. 20kW, 50kW and 80kW solar PV array. At all the different power capacities the generation of EMI suppress satisfactorily. In addition, when this improved control strategy implemented on different inverter topologies, output results show that it will perform up to the mark.

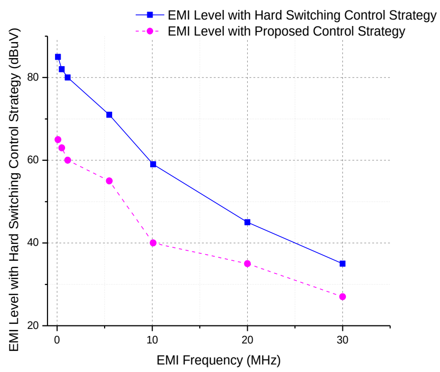
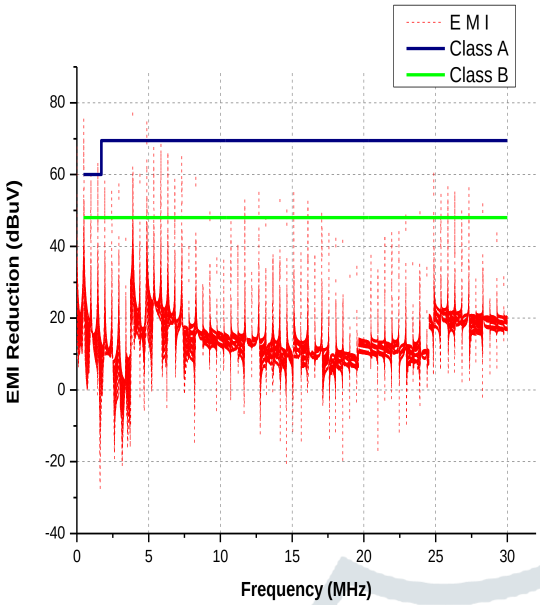


Fig. 1.7 Comparison between Hard & proposed control Technique



Sr. No.	Frequency MHz	EMI conventional control	EMI proposed control	Reduction of EMI
1	0.105	82	63	19
2	0.500	78	60	18
3	1.120	79	61	18
4	5.500	74	52	22
5	10.100	65	42	23
6	20.000	44	31	13
7	30.000	29	24	5

Fig. 1.8 Total EMI Generated when proposed control strategy applied

VII. Conclusion

With the implementation of improved control technique in grid connected PV system, there was a reduction in EMI generation. This main reason behind this reduction in EMI is lower the value of dv/dt. In case of improved control technique, the switching is done at zero crossing of voltage. It will lower the voltage stress on switching devices of inverters. Thus EMI level reduces. From the results, we observe that in case of proposed control technique, the EMI level is below the CISPR 22 standard. From the results, we conclude that the main reason of EMI generation is high dv/dt. If we reduce the dv/dt stress drastically then problem of EMI can be solved very easily. There are some other issues related to the EMI, which can also be solving with this proposed control method.

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